Table 1
IDENTITY OF SMELT SAMPLES BASED ON ALLOZYME ANALYSIS

| Site | Delta Smelt | Wakasagi Smelt | DxW Hybrids | DxL Hybrids |
|---|---|---|---|---|
| SWP | 100 | — | — | — |
| Chipps Island | 100 | — | — | — |
| Decker Island | 99 | — | — | 1 |
| Unknowns | | | | |
| Chipps Island | — | 1 | — | 3 |
| American River | — | 9 | — | — |
| Unknown | — | — | — | 1 |

1996) and the concomitant extension of the longfin spawning season to April and May (Sweetnam, personal communication), overlapping with that of delta smelt. The 1997 year class may include even more hybrid individuals because of the size of the 1995 longfin smelt year class. The relative size of the respective delta smelt population will also play a significant role.

We now know that hybridization takes place between delta smelt and both wakasagi and longfin smelt. No backcross individuals have been observed, suggesting that both F1 hybrids are infertile. Backcrossing is far more problematic than F1 hybridization because of the permanent flow of another smelt species' genes (introgression) into the gene pool of delta smelt. Interspecific hybridization among fish species is relatively common, even among endemic, sympatric species (Hubbs 1955; Schwartz 1972, 1981). The biggest concerns are that hybrids will compete for food and may compete for spawning space and mate availability with delta smelt.

Although hybridization and numbers of wakasagi in the estuary do not appear to be a problem at this time, the future remains unclear. Are the wakasagi spawning farther down in the estuary in each subsequent generation? If so, this situation will raise a number of additional questions. What is the limit to its spread? Is hybridization with delta smelt rare when both species are equally common? Do the wakasagi compete for food with delta smelt? Can the two species coexist in the estuary?

Similarly, major changes in abundance and spawning timing of longfin smelt may impact on the delta smelt population. Introductions of exotic organisms and alterations in the annual cycle of water flow in the estuary will likely have unexpected effects on indigenous species in the estuary.

The spawning grounds are the key to production of the next cohort of smelt (Moyle *et al* 1992). All of the samples in this study and prior years' samples have come after significant movement of larval smelt. No sampling has been done during spawning. Over the next few years we need to concentrate sampling at several key spawning areas and to sample several hundred smelt from each site to more accurately portray spatially and temporally the numbers of non-pure delta smelt in the estuary.

Finally, the question of potentially different spawning populations of delta smelt should be addressed. While the null hypothesis that there is only a single estuary population seems most likely, rejecting this hypothesis with a finding of genetically differentiated spawning populations would alter dramatically how we perceive this organism and how we would manage it. An analysis of four populations from the extremes of the estuary would address this question.

Diversity of data types (water chemistries, water movement, plant abundance, predator abundance, smelt population structure, *etc*) is needed to understand and predict the long-term viability of delta smelt in the Sacramento-San Joaquin estuary.

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# Summer Tow-Net Survey: 1995 Young-of-the-Year Striped Bass Index

*Stephen F. Foss and Lee W. Miller (DFG)*

The summer tow-net survey provides an index of young-of -the-year striped bass abundance and has been conducted every year since 1959, except for 1966 when no boat was available. The index estimates abundance when the mean length of the catch equals 38mm (Turner and Chadwick 1972). Surveys require 5 days of sampling. They are conducted every second week, usually starting in late June and continuing until the mean length of 38mm is reached or exceeded. The index is usually set in mid-July, but it has been set as early as June 22 and as late as August 12. We sample 31 stations in Suisun Bay and the Sacramento-San Joaquin Delta (Figure 1). This report describes reasons for not measuring an index in 1995 and the evidence that abundance was unusually low for a wet year.

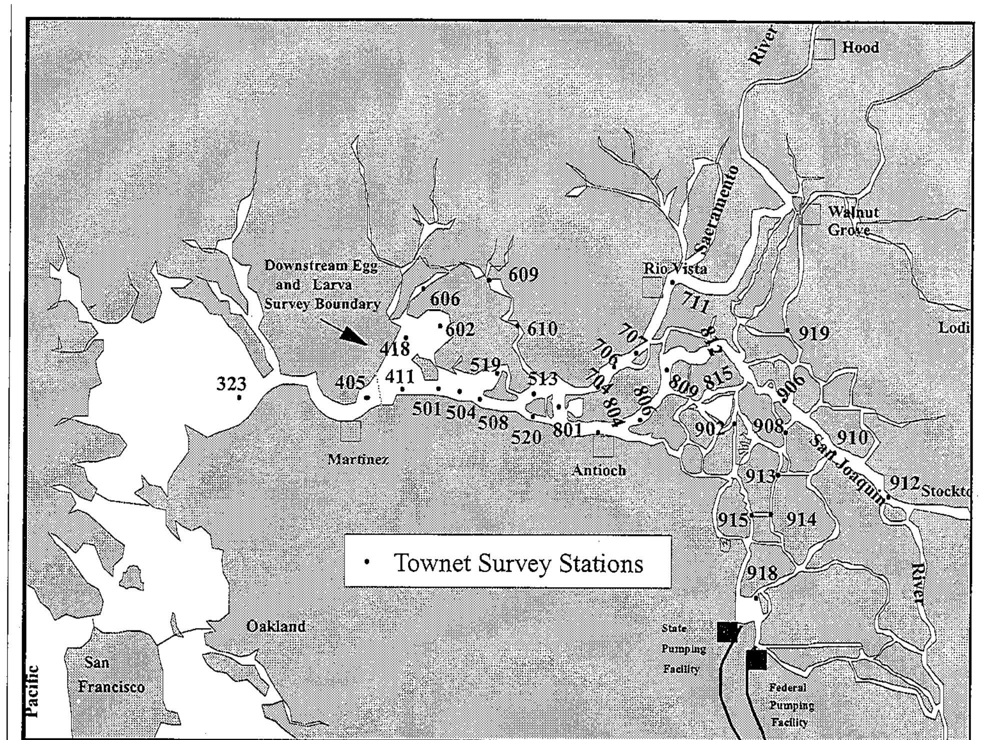


Figure 1
TOW-NET STATIONS AND LOWER BOUNDARY OF THE 1995 EGG AND LARVAL SURVEY STATIONS

## 1995 Index

The 1995 Tow-Net Survey consisted of five biweekly surveys. The first began July 3, and the last ended September 1, the latest ending date ever. No index was measured in 1995 because the mean length of fish in the sample did not reach the 38mm index size by the fifth survey, when no further sampling was justified because of low catches. The 1995 abundances for the first four surveys, though low, were not the lowest in recent years. Abundance for the fifth survey was, however, the lowest observed. An unusual nonprogression in the mean length also occurred between surveys four and five (Figure 2). The slow progression in mean length over all surveys was apparently caused by continued recruitment of small fish to the gear and relatively low abundance of large fish.

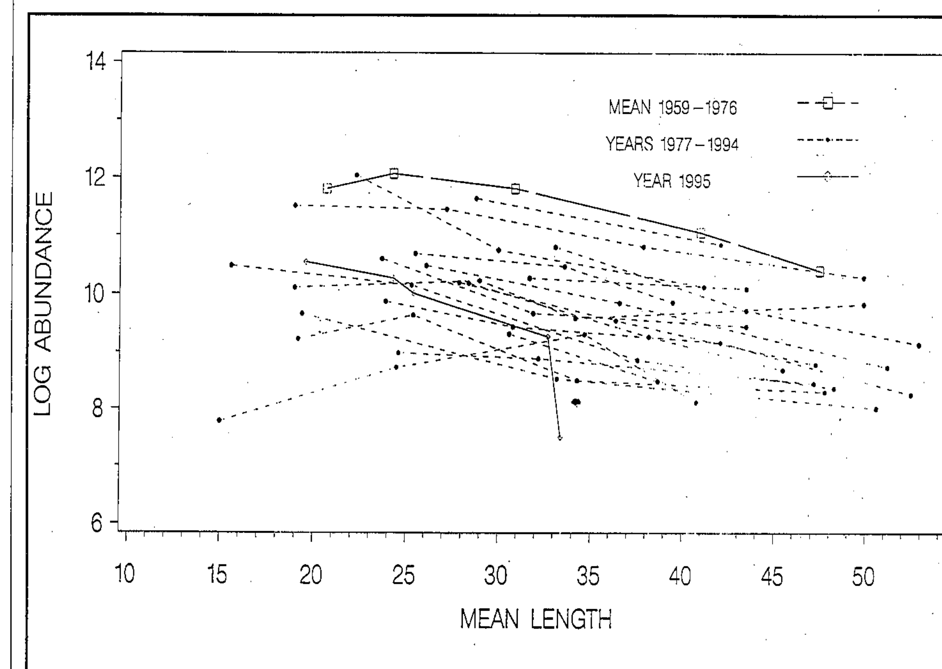


Figure 2
RELATIONSHIP OF LOG ABUNDANCE OF STRIPED BASS TO THE MEAN LENGTH OF THE CATCH SINCE 1977 AND THE AVERAGE FOR YEARS BEFORE 1977

What caused these unusual results? We examine several explanations for this:

- Late recruitment to the gear of smaller fish due to prolonged spawning.
- Low numbers of large fish due to: gear avoidance by larger fish, high mortality of large fish between surveys four and five, or overall low abundance of striped bass resulting in reduced probability of encountering large fish late in the year.
- Overall low abundance in the survey caused either by downstream location of fish such that they were not sampled or by early life-stage mortality and/or low spawning stock.

## Prolonged Spawning

The proportion of striped bass <25mm persisted in 1995 compared to 1982, a year with a more typical size distribution, suggesting a prolonged spawning period (Figure 3). We looked at water temperature patterns to see if they could have caused a prolonged spawning period. An important cue for striped bass spawning is a rise in temperature (IESP 1991). There were at least three substantial rises in Sacramento River temperature during the 1995 spawning period; the first was in late April (Figure 4). Sacramento River water temperatures in 1995 exceeded the spawning threshold for a longer period during late April than in 1983, a comparable high-outflow year. Since we have no egg occurrence data from the spawning grounds for either year, we can only speculate about what happened. In both years the most significant spawning likely would have been during the second large rise in temperature in mid-May. Although most spawning in 1995 would likely have been completed by the late June temperature rise, a 14mm striped bass caught in late August indicates some bass spawned in late July. San Joaquin River water temperatures followed a similar pattern and did not differ substantially from those of other recent wet years.

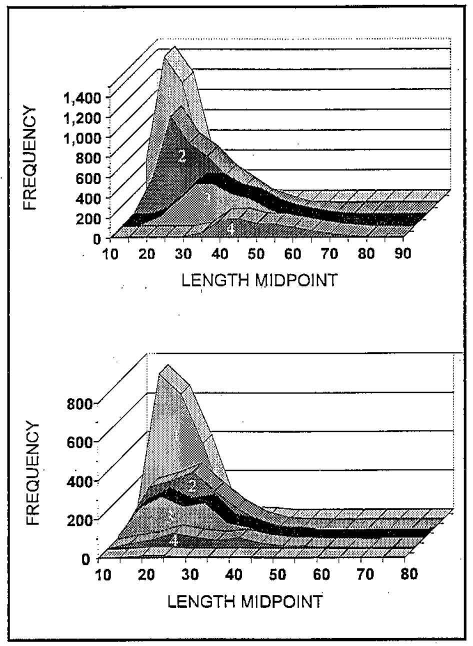


Figure 3
LENGTH FREQUENCY DISTRIBUTIONS FOR 1982 (top) AND 1995 (bottom)
*The 1982 distribution is typical of those seen in wet years.*
*Surveys 1-4 are labeled.*

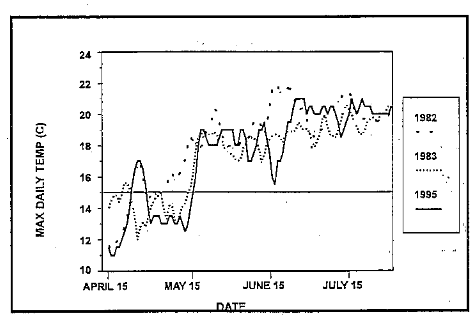


Figure 4
SACRAMENTO RIVER WATER TEMPERATURE AT GRIMES FOR THREE HIGH-OUTFLOW YEARS

## Gear Avoidance

Larger striped bass can avoid the sampling gear better if water transparency is high. Secchi disc readings from the 1995 Tow-Net Survey were high relative to other wet years but were not higher than some recent drought years for which an index was obtained (Figure 5). The average secchi reading between the fourth and fifth surveys in 1995, when fewer large fish were caught, decreased from 52cm to 48cm. Therefore, gear avoidance due to high water transparency in the sampling area is an unlikely cause of capturing fewer large fish.

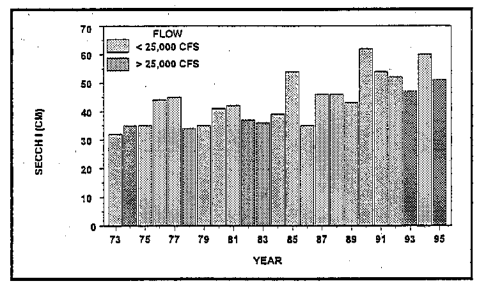


Figure 5
MEAN SECCHI DISC READINGS FOR TWO TOW-NET SURVEYS BRACKETING THE INDEX DATE
*Specific Conductance <6mS/cm.*
*Years are divided into those with April-July outflow <25,000 cfs and those with April-July outflow >25,000 cfs.*
*Surveys 4 and 5 used for 1995.*

## High Mortality or Low Encounter

We calculated decline in numbers for fish >38 mm between the surveys that normally bracket the 38mm index date for high outflow years and found that the decline of fish >38mm in 1995 was greater than in other high outflow years (Table 1). Decline for all other years averaged 1.0 and ranged from 0.37 to 1.66. We cannot discern whether this high 1995 decline rate occurred because there were simply few large fish to encounter in the population, or whether it was due to high mortality between surveys four and five. Few fish, patchily distributed, coupled with the lateness of the survey could have contributed to this unusual decline.

Table 1
DECLINE IN NUMBERS OF STRIPED BASS >38mm BETWEEN THE LAST TWO SURVEYS FOR HIGH-OUTFLOW YEARS

| Year | Catch at Survey (n) | Catch at Survey (n+1) | n+1/n |
|---|---|---|---|
| 1963 | 1624 | 1119 | 0.69 |
| 1967 | 1581 | 1302 | 0.82 |
| 1969 | 1020 | 1416 | 1.38 |
| 1974 | 1503 | 1224 | 0.81 |
| 1982 | 968 | 865 | 0.89 |
| 1983 | 173 | 479 | 2.77 |
| 1993 | 404 | 430 | 0.64 |
| 1995 | 113 | 21 | 0.17 |

## Downstream Location

In high-flow years, young-of-the-year striped bass may be distributed downstream of our sampling area. Such a distribution occurred in 1967 and 1983, causing striped bass 38mm indices to be biased low, based on relatively high fall midwater trawl abundance. Downstream distribution of young-of-the-year may result from a "washout" of larval fish. We define washout as flushed past the sampling area by high flows and, hence, geographically unavailable to the sampling gear.

Did washout occur in 1995? Delta outflow for May 3-11 was unusually high, averaging 146,000 cfs (Figure 6) and occurred followed a period of rising water temperature in late April during which significant spawning may have occurred (Figure 7). The egg and larval survey catch per tow during this period for Sacramento River stations from Martinez to Rio Vista and San Joaquin River stations downstream of Threemile Slough show a slight increase, indicating some spawning. Striped bass spawned before mid-May probably were washed out, since flows of about 60,000 cfs historically have moved the center of 6mm larvae distribution downstream of the egg and larval sampling area lower boundary (Figure 8). After May 26, a large cohort of larvae appeared in the egg and larval data concomitant with declining flow and rising temperature. This cohort would be at least partially retained in the tow-net survey sampling area, which extends farther downstream than the egg and larval sampling area, because after May 26 flows were less than 64,000 cfs. Also, striped bass caught in the 20mm survey, which is designed for delta smelt and has sampling stations corresponding to those of the tow-net survey, increased in mean length from May 22 to July 31 (Table 2), indicating that some if not all of this cohort was retained in the sampling area rather than being flushed out as larvae.

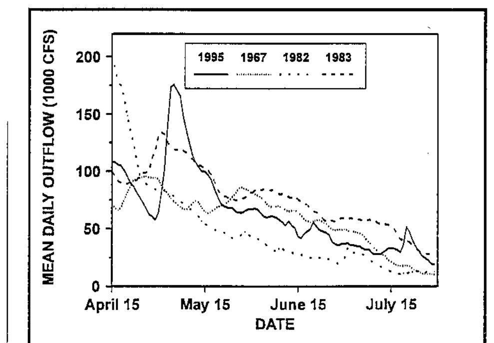


Figure 6
MEAN DAILY DELTA OUTFLOW DURING APRIL 15 - JULY 28 FOR FOUR HIGH OUTFLOW YEARS

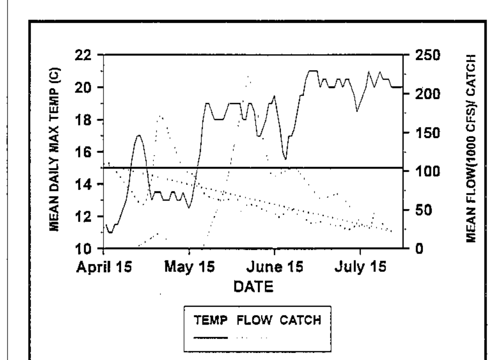


Figure 7
MEAN DAILY DELTA OUTFLOW, MEAN DAILY MAXIMUM SACRAMENTO RIVER TEMPERATURE AT GRIMES, AND MEAN EGG AND LARVAL SURVEY STRIPED BASS CATCH PER TOW, APRIL 15 - JULY 28, 1995
*Catch data have not been standardized for unit effort.*
*The reference line at 15°C indicates the striped bass spawning threshold.*

Other evidence of larvae washout in high-outflow years is available. The San Francisco Bay Outflow Study's larval fish data indicate that in 8 of the 10 years sampled, few or no larval striped bass were found in San Pablo Bay or San Francisco Bay, but some were caught in high outflow years 1982 and 1983 (Table 3). No larval fish sampling was done in 1995, but since the mean April-July delta outflow in 1995 (66,000 cfs) was

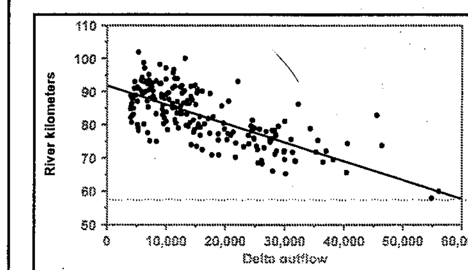


Figure 8
CENTER OF DISTRIBUTION OF 6mm STRIPED BASS FOR HIGH-FLOW YEARS IN RELATION TO DELTA OUTFLOW FOR THE SAMPLE DAY
*Daily 6mm data are from the DFG egg and larval database and daily flows are from the DAYFLOW database. The relationship may over-estimate the flow required to move the center of distribution beyond the boundary, because fish beyond the boundary are not sampled.*

Table 2
TOTAL CATCH AND MEAN LENGTH OF STRIPED BASS 1995 20mm Survey

| Survey | Start Date | Total Catch | Mean Length |
|---|---|---|---|
| 1 | April 24 | 31 | 4.2 |
| 2 | May 8 | 7 | 9.0 |
| 3 | May 22 | 949 | 7.7 |
| 4 | June 5 | 820 | 11.9 |
| 5 | June 19 | 5241 | 14.0 |
| 6 | July 3 | 4120 | 16.3 |
| 7 | July 17 | 2339 | 19.7 |
| 8 | July 31 | 1485 | 21.8 |

comparable to 1982 (61,000 cfs) and less than 1983 (83,000 cfs), we would expect that larvae were present in San Pablo Bay in 1995.

Table 3
LARVAL STRIPED BASS CATCH IN SAN PABLO BAY AND SAN FRANCISCO BAY
1980-1989 Bay Studies

| Year | Catch |
|---|---|
| 1980 | 1 |
| 1981 | 0 |
| 1982 | 50 |
| 1983 | 64 |
| 1984 | 0 |
| 1985 | 0 |
| 1986 | 1 |
| 1987 | 0 |
| 1988 | 0 |
| 1989 | 0 |

We also compared young-of-the-year striped bass abundance from four sampling efforts in San Pablo Bay in 1995 and 1983, the 2 years of highest mean April-July outflow, to evaluate downstream occurrence. Sampling efforts we compared include: the original San Pablo Bay tow-net station, the five added San Pablo Bay tow-net stations, the fall midwater trawl survey, and the Bay Study otter and midwater trawls (Table 4). Four of the five estimates of percent abundance in San Pablo and San Francisco bays were lower in 1995 than in 1983. The percent of total abundance for the added tow-net stations and fall midwater trawl survey suggests that at least 12-14 percent of the abundance was unaccounted for by our sampling in 1995. Proportions of fish downstream based on the Bay Study sampling were higher than for the fall midwater trawl survey, but since it under-samples the delta it over-estimates the proportion in the lower bays. We also recognize that we could grossly under-estimate downstream abundance if striped bass disperse into shallow, inshore areas where they are unavailable to the surveys. Clearly though, the bias due to fish being washed out was less than in 1983, another year when no valid tow-net survey index was measured. The 1983 midwater trawl survey did yield the second highest fall abundance index in 27 years of record.

## 1995 Abundance

Although no index was measured, the relatively low index for each survey (survey 1=37.9, survey 2=28.9, survey 3=22.3, survey 4=10.6, survey 5=1.8) indicated low abundance in 1995. Using data for only the first four surveys, we estimated an index, by regressing log abundance on mean length (log abundance = 12.57 −0.0998 * mean length; R2=0.9759, P>F=0.012). The predicted 38mm index based on an extrapolation of this regression was 6.4. Additional evidence for low young-of-the-year abundance comes from the 1995 fall midwater trawl survey. The fall striped bass abundance index of 523 was the third lowest of record. We used the fall index to predict 38mm abundance in 1995 by regressing the 38mm index on the fall index for years of record 1968 to 1994. We eliminated the 1967 data to establish a linear relationship between abundances (38mm abundance = 6.752 +0.00762*midwater trawl index; $R^2$=0.654; P>F=0.0001). This hind-casting approach predicted a 38mm index of 10.7 (95% confidence interval 1.1-20.4). Based on these two approaches, we are confident that 1995 abundance was low despite an apparent under-estimate of San Pablo Bay abundance. The extrapolated 38mm abundance index was exceptionally low for a high-outflow year (Figure 9).

## Why Low Abundance in a High-Outflow Year?

Abundance for other species with positive abundance/flow relationships was not low. Fall midwater trawl abundance indices were high in 1995 for both splittail and American shad, suggesting the low striped bass abundance was not part of an general decline in fish production.

Table 4
YOUNG-OF-THE-YEAR STRIPED BASS CATCH PER TOW AND PERCENTAGE OF WEIGHTED CATCH PER TOW FROM SAN PABLO BAY BY FIVE SAMPLING EFFORTS IN TWO HIGH-OUTFLOW YEARS
*Percent of Total Weighted CPUE*

| Sample | 1983 | 1995 |
|---|---|---|
| Tow-Net[1] (original station) | 16.0 | 2.7 |
| Tow-Net (added stations) | 21.8 | 12.0 |
| Fall Midwater Trawl[2] | 47.2 | 14.5 |
| Bay Study Otter Trawl[3] | 56.4 | 26.5 |
| Bay Study Midwater Trawl[4] | 1.7 | 18.5 |

1 Percent of total YOY index at that station, first four surveys included.
2 Percent of total weighted YOY abundance index, September-December.
3 Percent of total weighted catch per hectare, September-December.
4 Percent of total weighted catch per hectare-meter, September-December.

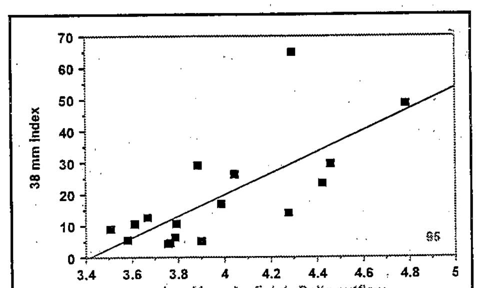


Figure 9
RELATIONSHIP OF 38mm STRIPED BASS ABUNDANCE INDEX TO MEAN APRIL-JULY DELTA OUTFLOW SINCE 1977



The DFG striped bass model (Kohlhorst *et al* 1992) using April-July delta outflow, April-July delta diversions, and 1994 egg production (1995 egg production estimates are not yet available) predicted a young-of-the-year index of 45.5, whereas our extrapolated index was 6.4. Over-prediction might be caused by poor survival of larval striped bass early in the spawning season and the fact that the 1995 egg production was likely lower than 1994 production due to the general declining trend in adults. This would result in fewer fish produced from later spawning after any early losses. However, using even greatly reduced estimates of egg production to account for these factors could not explain the low 1995 striped bass abundance. Modeling with an egg production value only 25% of 1994 estimated egg production still predicted an index of 31.8.

Low 1995 abundance could have resulted from high mortality of either eggs or larvae before the tow-net survey began in early July. We evaluated whether low food supply could have caused high larval mortality by comparing zooplankton and *Neomysis* concentrations for May-June 1995 with those of other years in two specific conductance ranges where larvae were located. One range, 1-6 mS/cm, is a practical representation of the entrapment zone; the other, <1 mS/cm, represents fresh water upstream of the entrapment zone. We included crustacean zooplankton observed in the diet of larval striped bass or similar to those so identified. *Neomysis* were used because their contribution to the diet begins when the larvae are about 10 millimeters long and increases with increasing size. *Acanthomysis*, an exotic species accidentally introduced about 1994, was included because it is similar in size to *Neomysis*.

One caveat in this analysis is that zooplankton and *Neomysis* sampling was greatly reduced in 1995 compared to years before 1994. Also, sampling of the entrapment zone was less than planned because of difficulty in locating the full range of entrapment zone specific conductance. Nonetheless, a high mean concentration of zooplankton in the entrapment zone in 1995 was observed (Figure 10). The 1995 *Neomysis* concentration was the lowest of record for the sampling reach where specific conductance is <1 mS/cm, but zooplankton was not unusually low in this reach. Hence the evidence that low food supply caused low abundance of striped bass is inconclusive.

Another speculative reason for high larval mortality is that the entrapment zone, where young fish tend to accumulate, was in Carquinez Strait early in the season. Striped bass survival may be poorer in this deep channel compared to survival of fish that are spread out in the shallows of San Pablo Bay or Suisun Bay.

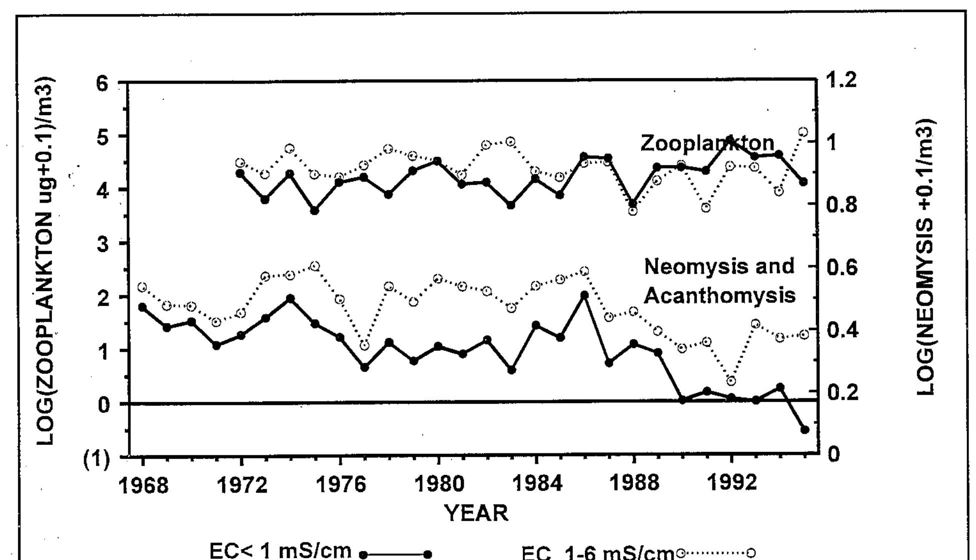


Figure 10
MEAN $LOG_{10}$ CONCENTRATIONS OF ZOOPLANKTON AND MYSIDS FOR TWO SPECIFIC CONDUCTANCE RANGES FOR MAY-JUNE FOR ALL YEARS OF RECORD

## Summary

We did not obtain an index, because mean size did not progress to 38mm during the survey. This lack of progression resulted from the capture of few large fish coupled with protracted recruitment of small fish to the gear. Abundance at 38mm predicted from partial summer data was 6.4 and from fall data was 10.7, thus quantifying a poor year class. Such a poor year class in a high-flow year is unusual in our time series, but the reason remains speculative. Most likely it is a result of high early mortality, which may be at least partly related to the high outflow in early May. Future estimation of recruitment to the adult stock will provide another opportunity to evaluate the strength of the 1995 year class.

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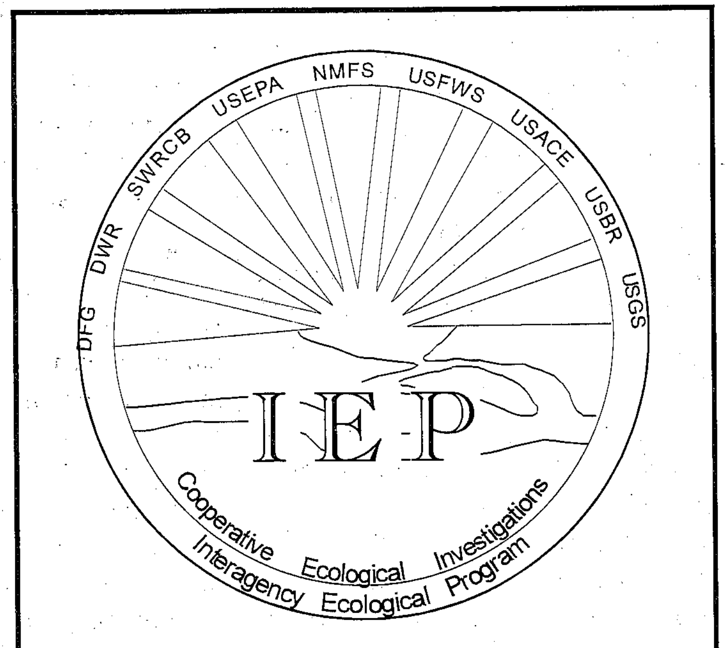
## Help Select a Logo

The Interagency Ecological Program is almost 30 years old and has no logo. In 1995, the Program Coordinators decided this major special study and monitoring collaboration should develop a logo for use on letterhead and for identifying Interagency Program products such as this *Newsletter* and our technical report series. Earlier this year, Interagency staff was invited to submit logo concepts for consideration. The Coordinators have reviewed several concepts and have narrowed the field to the three shown here. Now they want to know what you think. Contact Pat Coulston, Program Manager, to express your preference. You can even make suggestions for improving your favorite.

Pat can be reached at pcoulsto@delta.dfg.ca.gov or at 209/942-6068.

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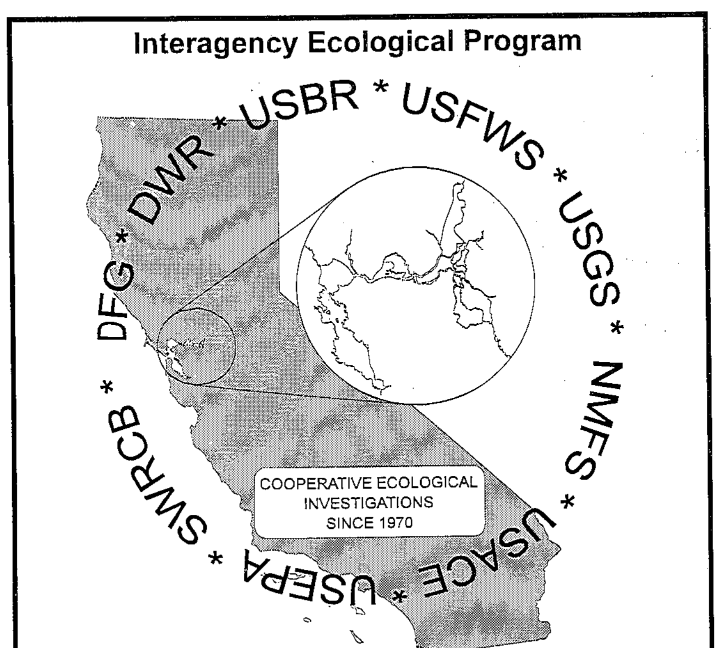
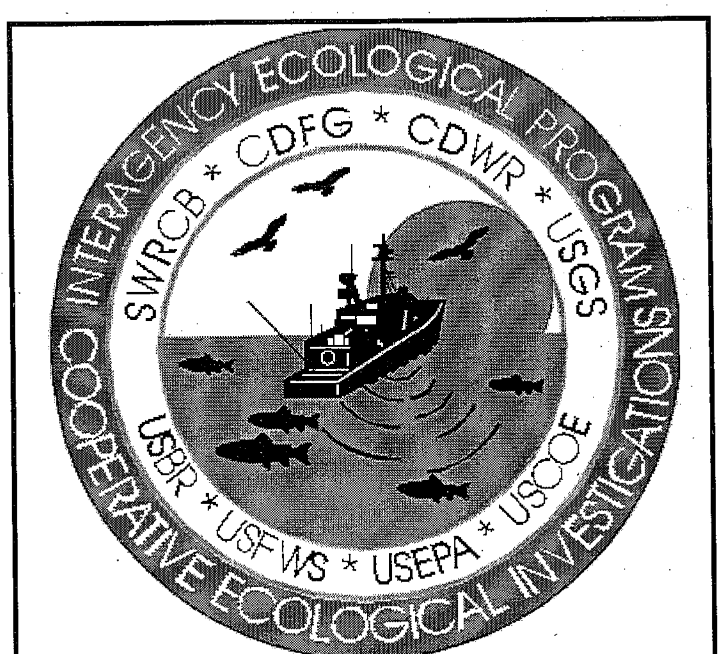



Logo A




Logo C



## Publication of "San Francisco Bay: The Ecosystem"

*James T. Hollibaugh*

Alien invasions, droughts, floods, toxic pollution and water use conflicts — these were the headlines for San Francisco Bay in the 80s and 90s. Although eye-catching, they provided a very shallow perspective of the news of the bay during this period. The deeper story concerns dramatic advances in our understanding of the bay as an ecosystem during this period — an understanding both driven by and underscored by these headlines.

Almost 20 years ago, Dr. T.J. Conomos organized a symposium on San Francisco Bay for the XXth annual meeting of the Pacific Division of the American Association for the Advancement of Science. The product of that symposium, *San Francisco Bay: The Urbanized Estuary* (edited by Dr. Conomos and published in 1979 by the Pacific Division AAAS), was the first comprehensive collection of papers on San Francisco Bay. This immensely popular volume — I was unable to find one at any price when I moved back to the Bay Area in 1983 and have been forced to rely on borrowing from a colleague a copy that has since disappeared (NOT to my personal library) — rapidly became the "bible" of research scientists, consultants, environmental lawyers, managers, and others concerned with San Francisco Bay. Although the collection was updated in a 1985 issue of *Hydrobiologia* that focused on a detailed study of the bay conducted in 1980 (Cloern, J.E., and F.H. Nichols, editors. "Temporal dynamics of an estuary: San Francisco Bay"), *The Urbanized Estuary* remains a primary reference on San Francisco Bay.

On both political and scientific fronts, the nearly two decades between publication of *The Urbanized Estuary* and the present have hosted a number of significant events. A series of hearings to determine, among other things, water allocations to protect bay aquatic resources focused the attention of managers and the general public alike on the bay during the latter half of the 1980s. Attention was sharpened by what appeared to be an unending series of drought years, possibly attributable to broad-scale climate change brought on by anthropogenic carbon dioxide emissions. These fears were erased, at least temporarily, by torrential storms and record floods during the winters of 1993 and 1995.

At the height of the drought an exotic species, the Asiatic clam *Potamocorbula amurensis*, was introduced to northern San Francisco Bay. Unlike many of its predecessors, establishment of this organism had devastating consequences for the bay. In slightly more than a year following its introduction in 1986, it became established throughout the bay. Its populations became so large in some areas, notably Suisun Bay, that standing crops of phytoplankton were decimated and primary production plummeted to about 20 percent of its previous value. In addition to competing directly with zooplankton for what appeared to be limited phytoplankton food resources, the clam impacted zooplankton populations directly by capturing juvenile stages of some species. Because these zooplankton were key food items for the larvae of some fish species, this posed the prospect of a cascading series of indirect negative impacts on the already beleaguered fish populations of the bay.

This series of events spurred new research and analysis of historical data focused on elucidating the relationship between freshwater inflows and ecological processes in San Francisco Bay and on understanding the bay as an ecosystem. This scrutiny raised many questions about our conceptual models of how the bay functions as an ecosystem. What are the sources of organic matter fueling bay productivity? What is the relationship between estuarine physics and biology or chemistry? What are the links between the bay and the Sacramento and San Joaquin rivers and their delta? How important is freshwater flow versus freshwater quality? How does the bay function physically, and what controls exchange with the ocean or circulation in the northern reach? Such scrutiny also focused more process-oriented research on the North Bay, where environmental research previously had been dominated by mandated monitoring programs.

Given the determined efforts to understand San Francisco Bay in the nearly two decades since the symposium on which *The Urbanized Estuary* was based, it seemed appropriate to consider organizing a similar symposium with the intent of producing a companion volume to update *The Urbanized Estuary* and present the emerging new paradigms. The 75th Annual Meeting of the Pacific Division, AAAS, held in San Francisco in 1994, provided the opportunity and Drs. T.J. Conomos and R.I. Bowman provided the encouragement and moral support needed to overcome my trepidation about the magnitude of the project. The result is this volume, which complements *The Urbanized Estuary*.

*San Francisco Bay: The Ecosystem*, edited by James T. Hollibaugh and published by the Pacific Division, American Association for the Ad-